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By K. MACKENZIE, B.Sc.
Marine Laboratory, Aberdeen
February, 1968

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Some Parasites of O-group Plaice, *Pleuronectes platessa* L., under Different Environmental Conditions

INTRODUCTION AND MATERIAL

Since 1964 several members of the staff of the Marine Laboratory in Aberdeen have been engaged in ecological studies in Loch Ewe, a sea loch on the north-west coast of Scotland. This loch supports a natural population of young plaice, around which much of the work is concentrated with a view to the application of the results in the field of fish husbandry. A survey of the parasite fauna of this natural population is now an integral part of the project and forms the basis for comparison with the parasite fauna of plaice kept under artificial conditions as described by Steele (1966) and in the present paper.

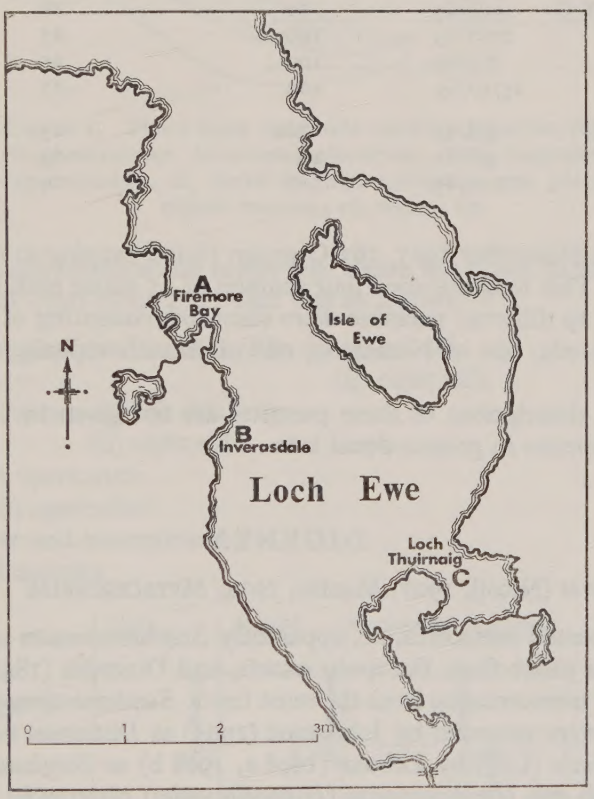

Figure 1. Chart of Loch Ewe showing sampling positions:
A. natural population in clean sandy bay;
B. fish in tanks on clean sand, open situation;
C. fish in tanks on muddy sand, sheltered situation.

Samples of twenty-five O-group plaice from the natural population at position A in Firemore Bay (Fig. 1) were examined every month from May to November, 1965. At Inverasdale and Thuirnaig (positions B and C respectively) plaice of the same age-group were kept for another purpose in tanks 12 ft × 6 ft × 1 ft high, the top and sides of which were constructed of fine-mesh netting and the bottom of canvas. The natural substrate at each position, containing many of the animals on which the plaice feed, was spread over the bottom of each tank. The tanks were immersed in about 6 ft of water sublittorally and rested on a clean sandy bottom

in an open situation at B, and on a muddy bottom in a sheltered bay at C. Nine tanks were immersed at each position and stocked with plaice in densities of 10, 30 and 100 fish per tank, three tanks with each density at each position. The tanks were immersed at the end of June and beginning of July 1965, and raised at intervals of 4 to 7 weeks thereafter, the last three tanks being raised at C on 9th November 1965. No plaice were recovered from these last three tanks.

As this was not originally designed as a parasitological study, sampling had to be fitted into the existing arrangements. The tanks stocked with 10 fish were not considered, as the number of fish in the sample would have been too small to give any significant result.

Sampling details for the tank experiments are as shown in Table I.

TABLE I

DETAILS OF FISH TANK SAMPLES

Position	Date	Population density	No. of fish in sample
A B	20/7/65	30	26
	20/7/65	100	25
	8/9/65	100	25
	25/10/65	100	25
C	4/8/65	30	15
	4/8/65	100	23
	20/9/65	100	24

From 20th July to 10th November 1965, 263 O-group plaice, ranging in size from 1·9 to 8·7 cm, were preserved in 10% formalin. This total included four samples of 25 plaice each from the natural population at position A. From these fish 19 different parasites were recorded, consisting of eight species of Digenea, one of Monogenea, three of Cestoda, one of Nematoda, one of Acanthocephala, one of Copepoda and four of Protozoa.

Detailed morphological descriptions of these parasites are not given in this paper as it is the author's intention to deal with each species in greater detail later.

DIGENEA

Stephanostomum baccatum (Nicoll, 1907) Manter, 1934, Metacercariae

Kroyer (1838–1853) reported metacercariae, apparently *Stephanostomum* sp., encysted in turbot, *Scophthalmus maximus* (L.), and in plaice from European waters, and Dujardin (1845) identified and described, as *Distoma hystrix* Duj., similar metacercariae from the same hosts. *Stephanostomum* sp. metacercariae encysted in flatfish from British waters were recorded by Johnstone (1905) as *Distomum valdeinflatum* Stossich from the common dab [*Limanda limanda* (L.)]; by Lebour (1908 a, 1908 b) as *Stephanochasmus baccatus* Nicoll from the common dab, long rough dab [*Drepanopsetta* (*Hippoglossoides*) *platessoides* (Fabricius) Malmgren], witch [*Glyptocephalus cynoglossus* (L.)], and lemon sole [*Microstomus kitt* (Walbaum)]; by Nicoll and Small (1909) as *Stephanochasmus baccatus* Nicoll from the common dab; and by Nicoll (1910) as *Stephanochasmus baccatus* Nicoll from the long rough dab. Wolfgang (1954 a, 1954 b, 1955 a, 1955 b) investigated metacercariae of *Stephanostomum* encysted in several flatfish species off the Atlantic coast of Canada and identified them as *Stephanostomum baccatum* Nicoll. The metacercariae from plaice discussed in this paper were specifically identified by feeding infested O-group plaice to *Cottus scorpius* L., under controlled experimental conditions and allowing the trematodes to develop to an identifiable stage. *C. scorpius* and halibut [*Hippoglossus hippoglossus* (L.)] are definitive hosts of *S. baccatum*.

The metacercariae were usually found encysted in subcutaneous tissue but occasionally in other sites. Each metacercaria was doubled up in a U-shape inside a double-walled capsule, the inner wall of which was a thin transparent membrane formed by the parasite, while the thick, opaque, white outer wall was formed

as a host tissue reaction. In the July samples the inner cyst diameter was 300–350 μ and the outer cyst diameter 350–380 μ; the metacercariae at this stage were small, with prominent eye-spots and oral spines just beginning to develop. By November the metacercariae were much larger, the diameters of the inner and outer cysts were 550–650 μ and 850–900 μ respectively, the eye-spots were fading noticeably and the oral spines were 48–50 in number and well-developed. All the metacercariae from any one sample were at approximately the same stage of development, indicating a strictly seasonal type of life cycle.

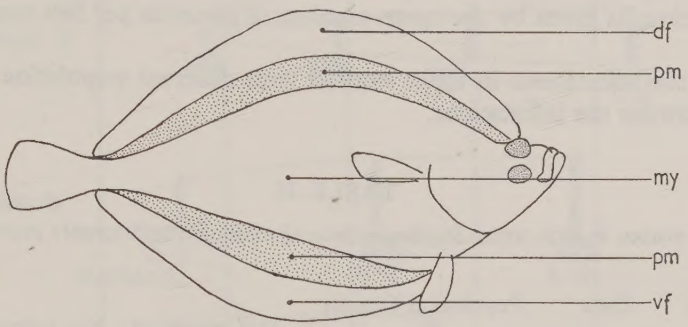

Figure 2. Plaice from right side showing principal sites of *Stephanostomum baccatum* infestation: semi-diagrammatic representation, df, dorsal fin; my, myotomes; pm, pterygiophoral muscles; vf, ventral fin.

The exact location of each metacercaria in the host tissue was noted in all the plaice examined. The percentage distribution of 1,268 cysts from 263 plaice was as follows:—

Pterygiophoral muscles (Fig. 2)	(i) left side	47·8%
	(ii) right side	12·8%
Myotomes	(i) left side	27·4%
	(ii) right side	7·2%
Left operculum		2·8%
Right operculum		None
Liver and mesenteries		1·5%
Gill muscles		0·5%

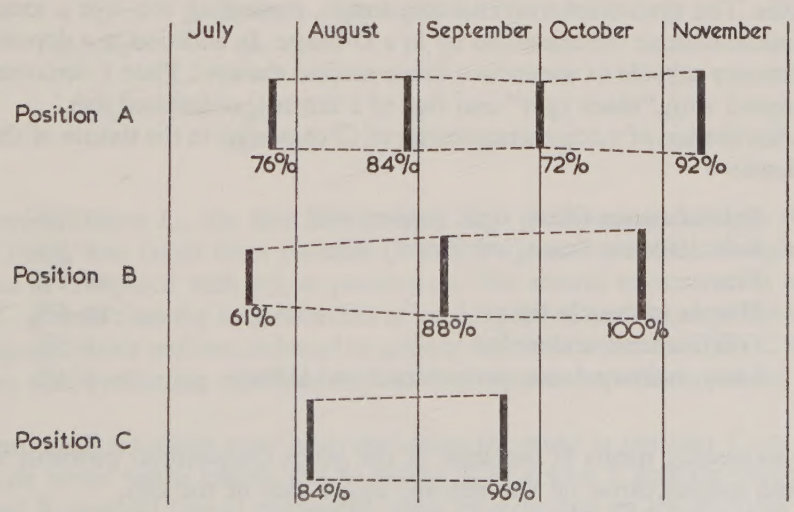

Figure 3. Incidence of *Stephanostomum baccatum* infestation in three environments during course of experiment.

The most significant point to emerge from these observations was the difference between the numbers of metacercariae encysted on opposite sides of the body. Seventy-eight per cent of all the cysts were located on the left side, i.e. the blind or lower side of the plaice, as compared with only 20% on the right or upper side. Whether this is related to any difference in the nature of the skin of the host on opposite sides of the body or to the behaviour of the cercaria, or of the fish, is as yet unknown.

The percentage incidence figures for this parasite in each environment are shown in Figure 3. The distribution of the parasites per fish in some samples was non-random, i.e. it did not follow a Poisson distribution. Intensity of infestation, as given by the mean number of parasites per fish could therefore be misleading and is omitted.

Table II compares the infestations in tanks stocked with different population densities. There were no significant differences between the infestations.

TABLE II

INFESTATION OF YOUNG PLAICE WITH *Stephanostomum baccatum* AT DIFFERENT POPULATION DENSITIES

Position	Date	Population Density	Incidence		
			No. examined	No. infested	%
B	20/7/65	30	26	15	58
		100	25	16	64
C	4/8/65	30	15	13	87
		100	23	19	83

Cryptocotyle sp. Metacercariae

Nicoll and Small (1909) reported a metacercaria from plaice in the Firth of Clyde which they identified as *Cryptocotyle concava* (Creplin). The identification was based on the examination of a single specimen and purely on grounds of morphological similarity. Nicoll (1910) again recorded *C. concava* from plaice in the Firth of Clyde, but Wootton (1957) has thrown some doubt on these identifications by showing that *C. concava* in California infests a fresh-water gastropod and a fresh-water fish.

These metacercariae were the cause of the condition known as "black spot", the most obvious external evidence of parasitism in the O-group plaice investigated in Loch Ewe. The larvae were found mainly in subcutaneous tissue and on the fins, but were also frequently found deeper in the hosts' muscular tissues and occasionally on the gills. The cysts were oval and very tough, measuring 200–250 μ long by 150–200 μ wide, and within them the metacercariae were doubled up in a U-shape. In addition to a deposit of melanin the host tissue produced a secondary capsule of connective tissue around the cyst. Plate I demonstrates the appearance of a plaice heavily infested with "black spot" and that of a normal, uninfested fish.

The percentage distribution of 3,002 metacercariae of *Cryptocotyle* in the tissues of the 263 O-group plaice examined was as follows:—

Subcutaneous tissue, right (upper) side	37·4%
Subcutaneous tissue, left (lower) side	2·3%
Fins	28·8%
Deeper in muscle tissue	29·6%
Gill filaments and arches	1·7%
Liver, urinary ducts, pericardium and kidneys	0·2%

The very active swimming habits of cercariae of the genus *Cryptocotyle* probably accounts for the preponderance of encysted metacercariae on the exposed upper side of the fish.

The infestation figures for this parasite in the three different environments are given in Figure 4. The natural population samples from position A showed much lighter infestations than at either B or C. At position

C the tank raised and sampled on 20th September yielded an extremely heavy infestation, the intensity of infestation having increased almost tenfold in the seven weeks preceding 20th September. No plaice were recovered from the tanks raised at position C seven weeks later.

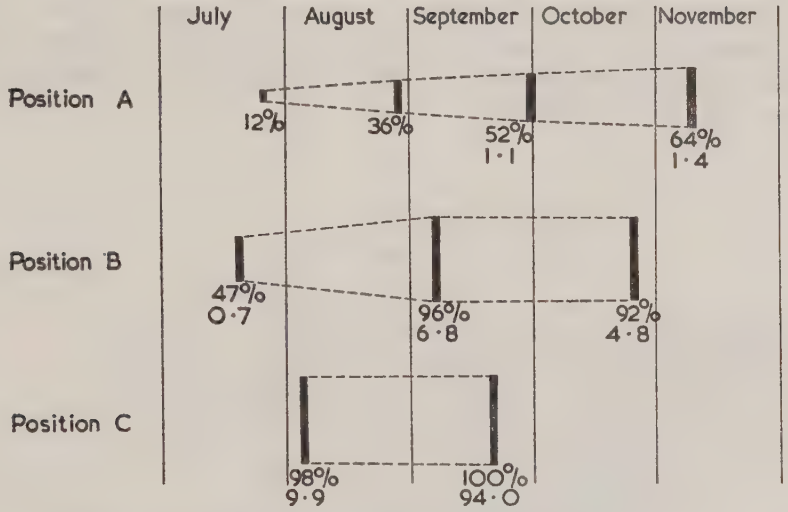

Figure 4. Incidence and intensity of *Cryptocotyle* infestation in three environments during course of experiment.

Table III compares the infestations in tanks stocked with different population densities. There were no significant differences between these infestations.

TABLE III

INFESTATION OF YOUNG PLAICE WITH *Cryptocotyle* sp. AT DIFFERENT POPULATION DENSITIES

			Incidence			
		Population density	No. examined	No. infested	%	Intensity
B	20/7/65	30	26	15	58	0·9/fish
		100	25	9	36	0·4/fish
C	4/8/65	30	15	14	93	8·3/fish
		100	23	23	100	11·0/fish

A sample of *Littorina littorea* L., the first intermediate host of *Cryptocotyle lingua* (Creplin), as demonstrated by Stunkard (1929), was taken from position C on 28th June 1966. This sample showed a 13% infestation with *C. lingua* as compared with 3% at position A. The littoral environments at positions B and C are more suitable for *L. littorea* than the long stretches of sand typical of position A. This is particularly true of position C, and consequently this mollusc is found in greater numbers there. Position C is sheltered from the main tidal currents, so that swimming cercariae will tend to accumulate there instead of being dispersed as at A and B.

As previously mentioned, no plaice were recovered from the tanks at position C on 9th November. Infestation by *Cryptocotyle* seven weeks earlier was so severe as to appear a possible cause of mortality in the plaice. Sindermann and Rosenfield (1954) conducted some experiments on the survival of O-group herring continuously exposed to large numbers of the cercariae of *C. lingua* and showed that fish thus exposed died within 15 days.

Rhipidocotyle sp. Metacercariae

These metacercariae were found almost exclusively in the dorsal and ventral gill muscles (Fig. 5). The larvae lay in a naturally extended position in fragile cysts which usually contained one metacercaria or occasionally two. The cysts were oval to spherical in shape, 200–400 μ long by 170–270 μ wide. The usual host reaction to an encysted metacercaria resulted in the formation of a secondary cyst around the primary one, but in this case the reaction was much less marked than with either *Stephanostomum baccatum* or *Cryptocotyle* sp. The metacercariae occasionally found in the myotomes or pterygiophoral muscles showed a much more pronounced host reaction than those in the gill muscles.

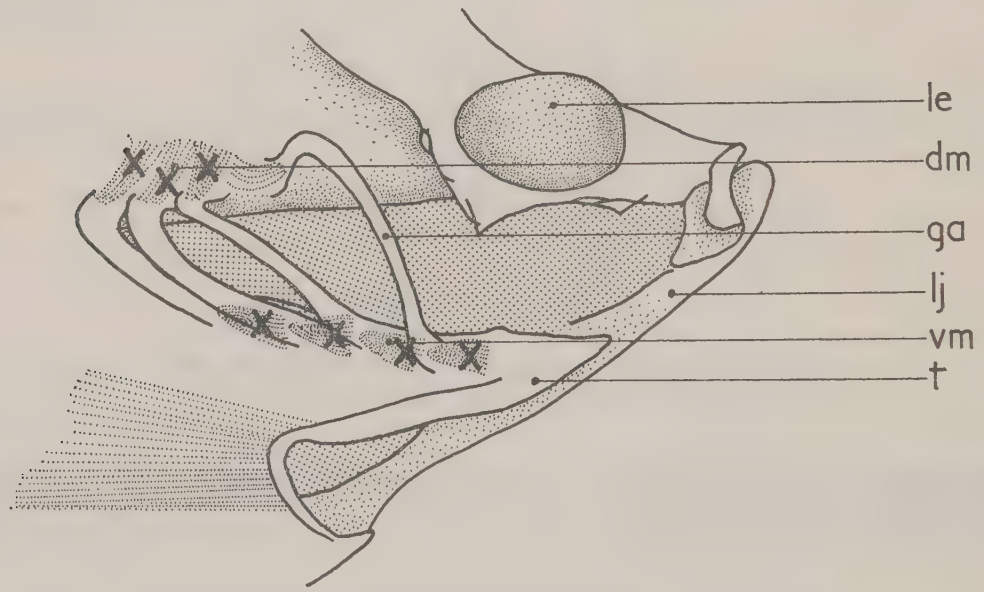

Figure 5. Plaice head with right side cut away to show sites of *Rhipidocotyle* infestation; semi-diagrammatic representation: dm, dorsal gill muscles; ga, gill arch; le, left eye; lj, lower jaw; t, tongue; vm, ventral gill muscles.

The exact locations of 462 metacercariae in the tissues of 164 O-group plaice were noted. About 99% of these were found in the gill muscles referred to above; the remainder were found in the opercula, pericardium, myotomes and pterygiophoral muscles. The distribution of metacercariae within the gill muscles is shown in Table IV, the most anterior gill on either side counting as No. 1.

TABLE IV

DISTRIBUTION OF *Rhipidocotyle* sp. IN GILL MUSCLES OF PLAICE

Gill Muscle	Number of metacercariae	Gill Muscle	Number of metacercariae
Left side dorsal No. 1	0	Right side dorsal No. 1	0
Left side dorsal No. 2	18	Right side dorsal No. 2	14
Left side dorsal No. 3	41	Right side dorsal No. 3	17
Left side dorsal No. 4	9	Right side dorsal No. 4	9
Left side ventral No. 1	37	Right side ventral No. 1	27
Left side ventral No. 2	50	Right side ventral No. 2	37
Left side ventral No. 3	78	Right side ventral No. 3	69
Left side ventral No. 4	32	Right side ventral No. 4	19

These observations show that infestation of the ventral muscles was three times as heavy as that of the dorsal muscles. The dorsal and ventral muscles on the left side of the head carried 58% of the parasites and those on the right 42%. The muscles controlling the movements of the two No. 3 gills between them carried 45% of the parasites.

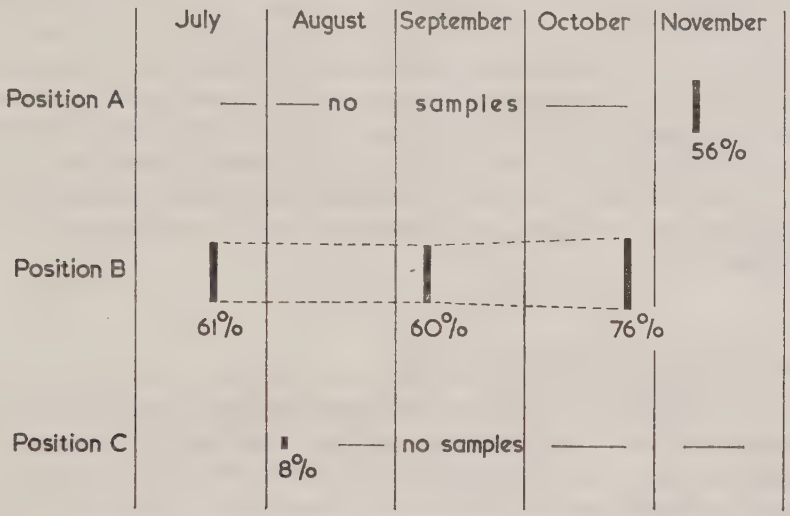

Figure 6. Incidence of *Rhipidocotyle* infestation in three environments during course of experiment.

Figure 6 shows the infestation data available for this species of *Rhipidocotyle*. Data on the intensity of infestation, as represented by the mean number of parasites per fish, are omitted for the reason given under *Stephanostomum* sp. The only complete records of *Rhipidocotyle* are from position B, but the incomplete records from the other positions suggest that this parasite is more common at the open sandy positions A and B than at the muddy sheltered position C. Trematodes of the family Bucephalidae, to which *Rhipidocotyle* belongs, invariably utilise lamellibranch molluscs as first intermediate hosts, and several hundred specimens from 12 lamellibranch species at positions A and B have been examined for bucephalids. So far only one species, *Mytilus edulis* L., has yielded a positive result, and the bucephalid cercaria from this mollusc is that considered by Chubrik (1952) to be a larval stage of *Prosorhynchus squamatus* Odhner.

Table V gives the percentage incidence data for the two levels of population density. The figures for position B, and to a lesser extent for C, show that the infestations were heavier in tanks of higher population density. A possible explanation of this is that these tanks rested in the close vicinity of one or more infested mollusc hosts, or that infested molluscs were present in or on the substrate on the bottoms of these tanks.

TABLE V

INFESTATION WITH *Rhipidocotyle* sp. AT DIFFERENT POPULATION DENSITIES

Position	Date	Population density	Incidence		
			No. examined	No. infested	%
B	20/7/65	30	26	11	42
		100	25	20	80
C	4/8/65	30	15	0	0
		100	23	3	13

Johnstone (1905) recorded a "*Gasterostomum* sp.", which present knowledge shows to be unmistakably a *Rhipidocotyle* sp., from the dorsal and ventral body margins of young plaice taken in Luce Bay in south-west

Scotland, and the author has seen this parasite in young plaice from Donegal Bay, on the west coast of Ireland, and from the Wash, on the east coast of England. According to Dr R. A. Matthews (Plymouth Technical College, personal communication), this species is progenetic, producing eggs a few weeks after encysting. The *Rhipidocotyle* sp. from Loch Ewe occupies an entirely different site in the host and infestations have now been followed over the course of 10 months with no sign of the metacercariae approaching sexual maturity. This suggests that in British waters there may be two species of *Rhipidocotyle* infesting plaice but with different geographical ranges. The Loch Ewe species has also been found in O-group plaice from Ardtoe in North Argyll, so that the boundary between the two species on the west coast would seem to occur between Ardtoe and Luce Bay. It is possible that the "northern" species exists farther south without having been recorded, but the "southern" species does not appear to extend much farther north than Luce Bay. An interesting parallel to this situation was discussed by Kabata (1967), when he recorded Irish Sea whiting as carrying a different species of myxosporidian gall-bladder parasite from whiting caught to the north and west of Ireland and in the Minches.

Podocotyle atomon (Rudolphi, 1802) Odhner, 1905

This trematode occurs in more than 20 species of marine fish in British waters and is well known as a parasite of fish in inshore habitats. The life history has been described by Hunninen and Cable (1943 a). Sporocysts and cercariae develop in the gastropod *Littorina saxatalis* (Olivi) and metacercariae are found in amphipods, principally *Gammarus* spp.

Adult forms of *Podocotyle atomon* were found in the intestine of O-group plaice at Loch Ewe. Mature and immature forms were found in equal numbers throughout the period covered by the experiments, the mature forms ranging in length from 0·77 to 2·20 mm and the immature specimens from 0·10 to 0·94 mm.

The fore-, mid- and hind-intestine of each fish was examined separately in order to ascertain a pattern of distribution for intestinal parasites. The distribution pattern for all the *P. atomon* specimens found in the 263 O-group plaice examined is given in Table VI.

TABLE VI

DISTRIBUTION OF *Podocotyle atomon* IN PLAICE INTESTINE

Section of intestine	Total number of *P. atomon*	Number of immature specimens	Number of mature specimens
Fore	21	15	6
Mid	26	13	13
Hind	46	18	28

Half of the total number of *P. atomon* were found in the hind-intestine, the other half being distributed fairly equally between the fore- and mid-intestine. Immature forms were distributed uniformly throughout the intestine, but mature forms were found mainly in the posterior third. The largest total number of specimens recorded from a single fish was seven; the largest number of mature specimens from a single fish was three.

Figure 7 gives the percentage incidence of *P. atomon* at each of the three positions in Loch Ewe. The infestations at all three were similar during August and September, but by the end of October the parasite had disappeared from the fish at position B. It is difficult to account for this decline in the infestation at position B, especially in view of its continued increase in later samples of the natural population at A. A slight change in environmental conditions at position B might have caused the migration of the parasite's second intermediate host from the vicinity of the tanks at B or it might have been eliminated by the fish from the substrate on the bottoms of the tanks so that no further infestation was possible.

The results from the different population densities at B and C are summarised in Table VII. In this case the situation at position B was reversed at C, although the numbers of infested fish were too small to be considered significant.

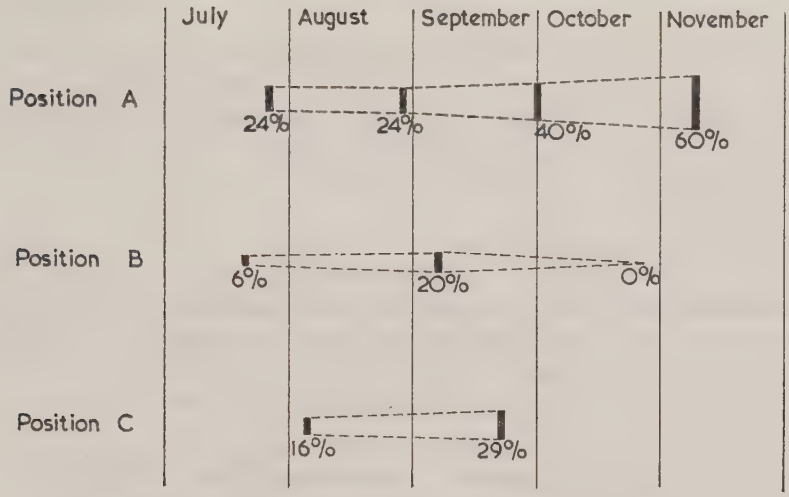

Figure 7. Incidence of *Podocotyle atomon* infestation in three environments during course of experiment.

TABLE VII

INFESTATION OF PLAICE BY *Podocotyle atomon* AT DIFFERENT POPULATION DENSITIES

Position	Date	Population density	Incidence		
			No. examined	No. infested	%
B	20/7/65	30	26	0	0
		100	25	3	12
C	4/8/65	30	15	4	27
		100	23	2	9

Zoogonoides viviparus (Olsson, 1868) Odhner, 1902

This is a common parasite of plaice in British waters, having been recorded by Nicoll (1907) at St Andrews, by Lebour (1908) at Cullercoats, by Johnstone (1909) at Liverpool, by Nicoll (1914) at Plymouth, by Nicoll (1915) at Aberdeen and Millport, by Little (1929) at Galway, by Baylis and Idris Jones (1933) at Plymouth and by Dawes (1947) at Plymouth. It has also been recorded from seven other flatfish species in British waters. Lebour (1918) described a cercaria from *Buccinum undatum* L. at Plymouth which she considered to be ". . . almost certainly a larval stage of *Zoogonus viviparus* (Olsson) . . .". However, the life cycle of this species remains unknown.

Zoogonoides viviparus was not found in plaice from the tanks, but 17 specimens were found in the natural population at position A in September and November. Ten of the 17 specimens were found in one plaice 8·7 cm long, the largest fish examined in the samples. All were found in the rectum.

Derogenes varicus (Muller, 1784) Looss, 1901

This species has been recorded from plaice in British waters by Nicoll (1910) at Millport, by Little (1929) at Galway and by Dawes (1947) at Plymouth. It has a wide range of definitive hosts and has been recorded from more than 40 species of marine fish in British waters. Progenetic metacercariae of *Derogenes varicus* have been recorded from *Sagitta bipunctata* Quoy and Gaimard in Plymouth Sound by Lebour (1917) and from the parasitic copepod *Lernaeocera lusci* (Bassett-Smith) at Roscoff, Finistère, by Dollfus (1954). Hall (1929) also recorded its occurrence in planktonic copepods of the genus *Acartia*.

D. varicus is by far the commonest of the three species of hemiurids observed in the O-group plaice at Loch Ewe. Table VIII shows its distribution in the alimentary tract of the infested fish.

TABLE VIII

DISTRIBUTION OF *Derogenes varicus* IN THE ALIMENTARY TRACT OF PLAICE

Section of Alimentary tract	Number of *D. varicus*	Number of immature specimens	Number of mature specimens
Stomach	91	62	29
Fore-intestine	9	5	4
Mid-intestine	1	1	0
Hind-intestine	3	3	0

Of the 104 specimens recorded, 33 were mature and 71 immature. All the mature forms were found in the stomach and fore-intestine and only four of the immature forms were found in the mid- and hind-sections of the intestine. The largest number of *D. varicus* recorded from a single fish was seven, all of which were immature; the largest number of mature specimens from a single fish was four.

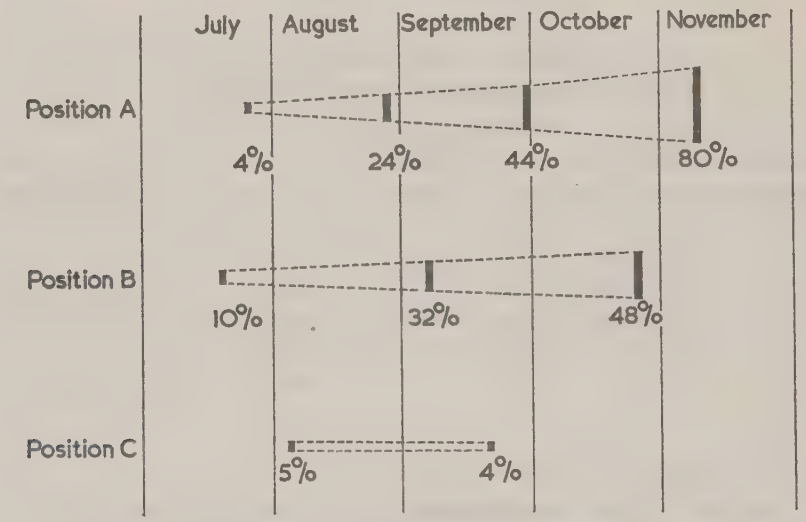

Figure 8. Incidence of *Derogenes varicus* infestation in three environments during course of experiment.

Figure 8 shows the percentage incidence of *D. varicus* at each position in Loch Ewe. The infestation at position C (three specimens from 62 fish) was very light compared with the infestations at A and B, which were similar to one another. The small bay in which C is located is sheltered from the main tidal currents, so possibly the planktonic, second intermediate hosts of hemiurid trematodes are swept past the entrance and are carried over the more exposed positions A and B.

The results from the different population densities at B and C are summarised in Table IX. There were no significant differences between these infestations.

TABLE IX

INFESTATION WITH *Derogenes varicus* AT DIFFERENT POPULATION DENSITIES

Position	Date	Population density	Incidence		
			No. examined	No. infested	%
B	20/7/65	30	26	2	8
		100	25	3	12
C	4/8/65	30	15	0	0
		100	23	2	9

Hemiurus communis Odhner, 1905

Little (1929) recorded this species from plaice at Galway on the west coast of Ireland. Like *D. varicus*, *H. communis* has a wide range of definitive hosts and has been recorded from more than 30 species of marine fish in British waters. Lebour (1923, 1935) identified as *Hemiurus communis* some metacercariae which she found free in the plankton and emerging from the planktonic copepod *Acartia clausi* Giesbrecht in Plymouth Sound. There are many other records describing and recording hemiurid metacercariae from planktonic copepods in various parts of the world.

Only six specimens of *H. communis* were recorded from the plaice samples taken at Loch Ewe; all were found in the stomach, two being mature and four immature. Five of these were from plaice in tanks at position B and one was from the natural population at position A. Not more than one specimen was found in any one fish.

Lecithaster gibbosus (Rudolphi, 1802), Luhe, 1901

Little (1929) recorded *L. gibbosus* from plaice at Galway. Like *D. varicus* and *H. communis*, it has a wide range of definitive hosts, occurring in more than 20 species of marine fish in British waters. The life cycle of *L. gibbosus* is unknown, but that of a closely related species, *L. confusus* Odhner, was described by Hunninen and Cable (1943 b) and shown to utilise copepods of the genus *Acartia* as second intermediate hosts.

Twenty-five specimens of *L. gibbosus* were recorded from the O-group plaice at Loch Ewe. Table X shows their distribution in the alimentary tract.

TABLE X

DISTRIBUTION OF *Lecithaster gibbosus* IN PLAICE ALIMENTARY TRACT

Section of Alimentary tract	Total number of *L. gibbosus*	Number of immature specimens	Number of mature specimens
Stomach	1	0	1
Fore-intestine	1	0	1
Mid-intestine	9	3	6
Hind-intestine	14	0	14

Most of these trematodes were found in the section of the intestine immediately anterior to the rectum and in the posterior half of the mid-intestine. The largest number recorded from a single fish was three—all mature.

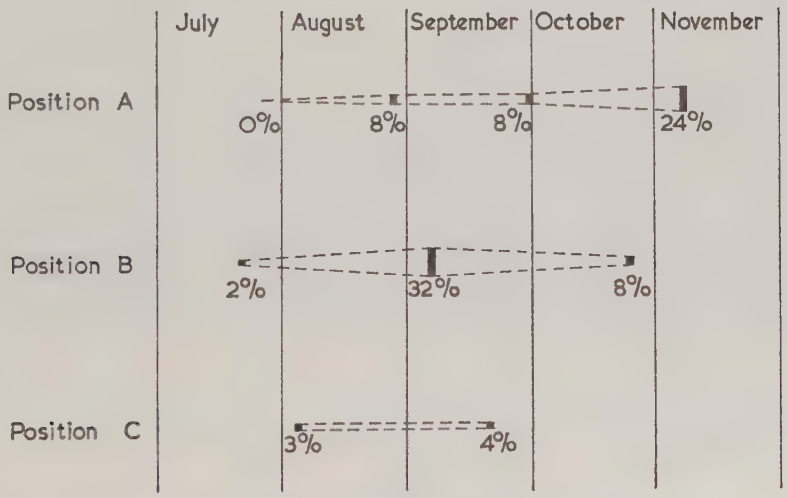

Figure 9. Incidence of *Lecithaster gibbosus* infestation in three environments during course of experiment.

Figure 9 shows the percentage incidence of *L. gibbosus* at the three positions in the bay. At B the infestation decreased from September to October, as for *P. atomon*, and in subsequent samples from position A in February and April, 1966, no *L. gibbosus* was recorded. It seems likely that this loss of infestation occurred about two months earlier at position B, as indeed did the original build-up of the infestation. The disappearance of *L. gibbosus* may well be related to either a change in the diet of the plaice or the disappearance of the second intermediate host from the area. As with the other two hemiurid species, the infestation with *L. gibbosus* at position C was lower than at A and B.

MONOGENEA

Gyrodactylus sp.

The first specimens of this parasite found on the plaice were sent to Dr K. M. Lyons (King's College, London) who compared them with species of *Gyrodactylus* known to occur on pleuronectids. In a personal communication she stated that they seemed likely to be *Gyrodactylus medius norai* Tripathi, 1959, which was first described by Sproston (1946) as *Gyrodactylus* sp. (? n. sp.) from the gills and fins of plaice at Plymouth. There appears to be no comprehensive description of *G. medius norai* in existence.

Gyrodactylus sp. was found on the gill filaments of O-group plaice at Loch Ewe and was just beginning to appear in the natural population samples about the time the tank experiments were ending. As a result the distribution pattern, as shown in Table XI, is based on only 55 specimens. The most anterior gill arch on each side is designated 1.

TABLE XI

DISTRIBUTION OF *Gyrodactylus* sp. ON THE GILLS OF PLAICE

Left side		Right side	
Gill No.	No. of *Gyrodactylus*	Gill No.	No. of *Gyrodactylus*
1	12	1	7
2	10	2	10
3	4	3	5
4	3	4	4

Although observations were few, Table XI suggests that this parasite may favour the two anterior gill arches on either side.

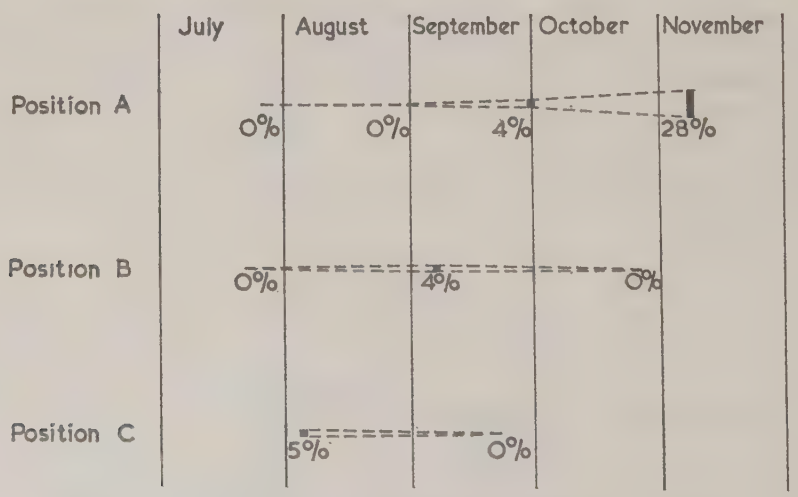

Figure 10. Incidence of *Gyrodactylus* infestation in three environments during course of experiment.

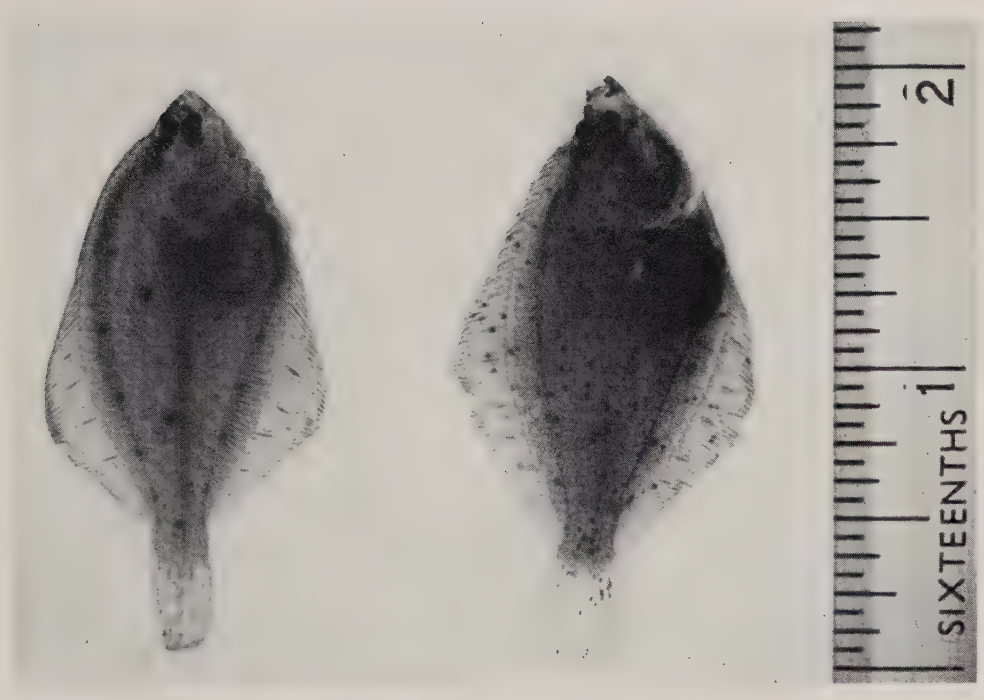

Plate I

Cryptocotyle infestation: uninfested fish (left) compared with heavily infested fish (right).

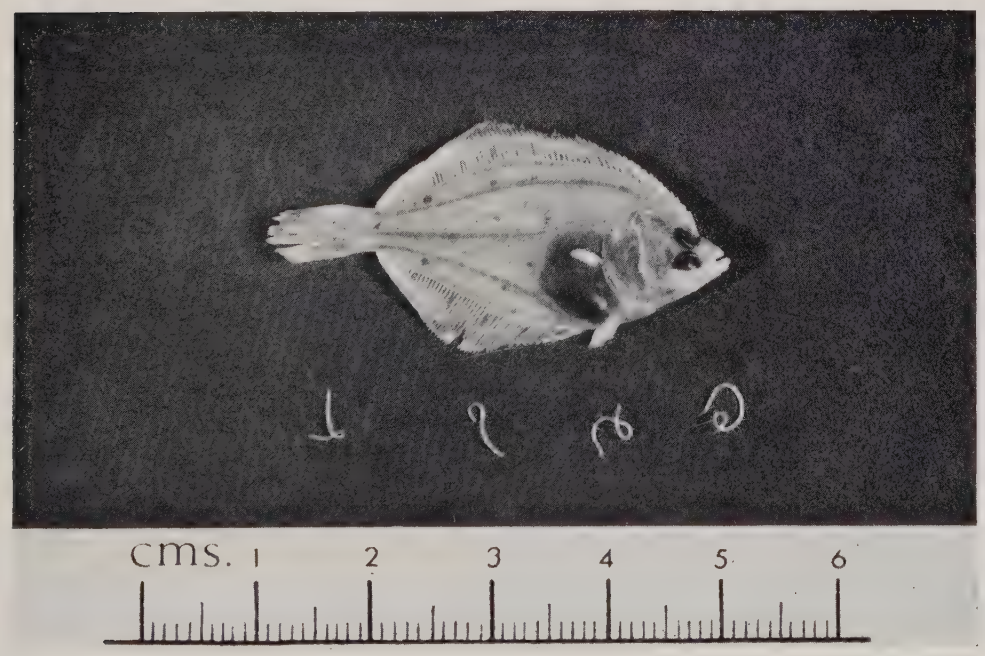

Plate II

Specimens of *Contracaecum aduncum* beside O-group plaice.

Plate III

Photograph of specimen, 250 μ long, of unidentified parasitic dinoflagellate.

Figure 10 shows the percentage incidence of *Gyrodactylus* sp. at the three positions. Only three infested fish were found in the tank samples, two of them among the 15 fish examined from the tank originally stocked with 30 fish at position C and raised on 4th August. Since these were the only two infested fish found in the first tanks raised at each position, no valid comparison of the infestations at different population densities can be made.

NEMATODA

Contracaecum aduncum (Rudolphi, 1802) Railliet and Henry, 1912

This is a very common parasite in many species of marine fish around the British coasts. Berland (1961) described the adult and larval stages of *Contracaecum aduncum* from Norwegian marine fish and discussed the probable life cycle. He concluded that ". . . planktonic invertebrates normally, and fishes occasionally, serve as first intermediate hosts, while fishes normally, and planktonic invertebrates occasionally, serve as second intermediate hosts. Fishes serve as definitive hosts."

In O-group plaice at Loch Ewe third-stage larvae were found encapsulated in the mesenteries or free in the coelom, usually coiled in a C- or S-shape. They measured 5–20 mm in length, and up to 11 specimens were recorded from a single fish. Plate II shows the large size of these nematodes relative to a plaice of 3·95 cm, which was the mean length of the plaice sampled at position C on 20th September.

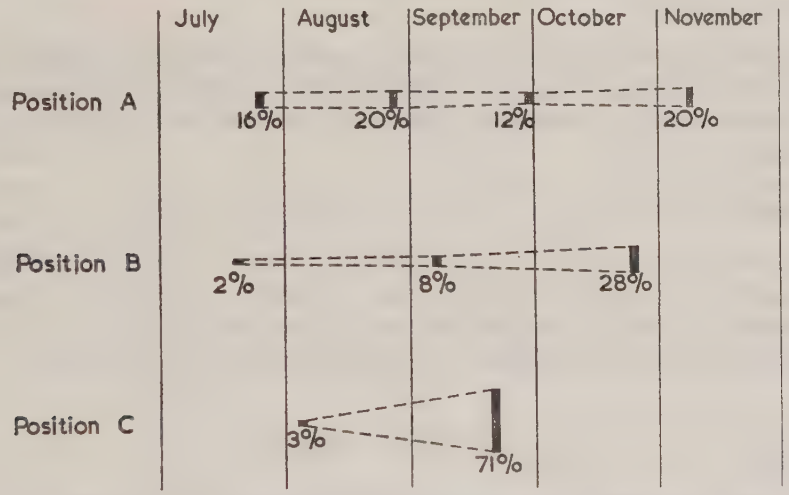

Figure 11. Incidence of *Contracaecum aduncum* infestation in three environments during course of experiment.

Figure 11 shows the percentage incidence of *C. aduncum* in plaice from the three positions. At position C between 4th August and 20th September the infestation increased from one infested fish in 38 to 17 in 24. At B the increase in infestation was much smaller during the time of the experiment, while in the natural population it remained fairly constant throughout. The effect of this infestation at position C may have supplemented that of *Cryptocotyle* sp. in bringing about the mortality in the last tanks raised.

Only two fish in the first tanks raised at position B and C carried this nematode, so no useful comparison of the infestations at different population densities could be made.

There are many records of *Contracaecum* sp. larvae from a wide variety of fish and planktonic invertebrates in various parts of the world, but if purely planktonic invertebrates were responsible for the heavy infestation at position C, one would also expect hemiurid trematodes to be well represented, whereas the incidence of this latter group at position C was very low. Mysids, which are semi-planktonic and are often present in large numbers in all parts of Loch Ewe, including position C, are more likely here to have been the vectors of the early larval stages of *C. aduncum*. They tend to move about near the bottom and would certainly come within the range of fish in submerged tanks. Scott (1957) recorded larvae of *Contracaecum* sp. from three species of

mysids, and R. R. C. Edwards (in manuscript) has shown that mysids form part of the diet of O-group plaice in Loch Ewe.

CESTODA

Nine of the 263 plaice examined were infested with plerocercoids of at least three different species of cestode. Of the nine infested fish, five came from samples of the natural population at position A and four from the tanks at position B; no plerocercoids were found in fish from position C. The definitive hosts of the tetraphyllidean and trypanorhynch plerocercoids are probably rays which are fairly common on the sandy bottom offshore from positions A and B.

Tetraphyllidean Plerocercoids

Four fish were infested with tetraphyllidean plerocercoids. One of these, from the natural population at position A on 20th July, carried five plerocercoids in its stomach, one in its fore-intestine and one in its mid-intestine. They ranged in length from 0·7 to 2·4 mm. The remaining three fish were from the tanks at position B, one on 8th September and two on 25th October. Each of these fish carried one plerocercoid, 1–2 mm long, in the hind-intestine.

Pseudophyllidean Plerocercoids

Three fish were infested with one pseudophyllidean plerocercoid each. From the natural population sampled on 31st August two fish were infested with plerocercoids, 5 and 10 mm long, irregularly coiled and embedded in the liver; one similar plerocercoid, 3 mm long, was found in a fish from the natural population examined on 30th September.

Trypanorhynch Plerocercoids

Two fish were infested with one trypanorhynch plerocercoid each. In the sample taken from the natural population on 31st August, one fish carried a plerocercoid, 12 mm long, coiled in a C-shape and embedded in the liver. In the sample from the tank at position B on 25th October, one fish carried a plerocercoid, 8 mm long, lying in an extended position in the visceral cavity along the surface of the kidneys.

ACANTHOCEPHALA

One larval acanthocephalan, pink in colour and 0·8 mm long, was found encysted between the liver and pyloric caeca of an O-group plaice from the natural population on 26th July.

PROTOZOA

Trichodina sp.

Many species of *Trichodina* have been described from a wide variety of marine and fresh-water fish in various parts of the world. Tripathi (1948) described *Trichodina branchicola* from the gills of eight species of marine fish at Plymouth, including one plaice. The species found on plaice in Loch Ewe is not *T. branchicola*.

Trichodina sp. was a very common parasite on the gills of O-group plaice in Loch Ewe. The method used in the examination of the gills of these small plaice for Protozoa was to macerate the gill filaments in a drop of water on a slide, place a $\frac{3}{4}$ inch square cover-slip over the drop and scan from one side of the cover-slip to the other three times, covering a different area each time. With a magnification of $\times 150$, individual organisms were clearly visible. Since the entire area of the cover-slip can be covered by 21 scans, by multiplying the number of organisms seen in 3 scans by 7, an estimate of the total number present on the gills was obtained. The highest estimate recorded in this way was 84, in a plaice from the natural population on 10th November.

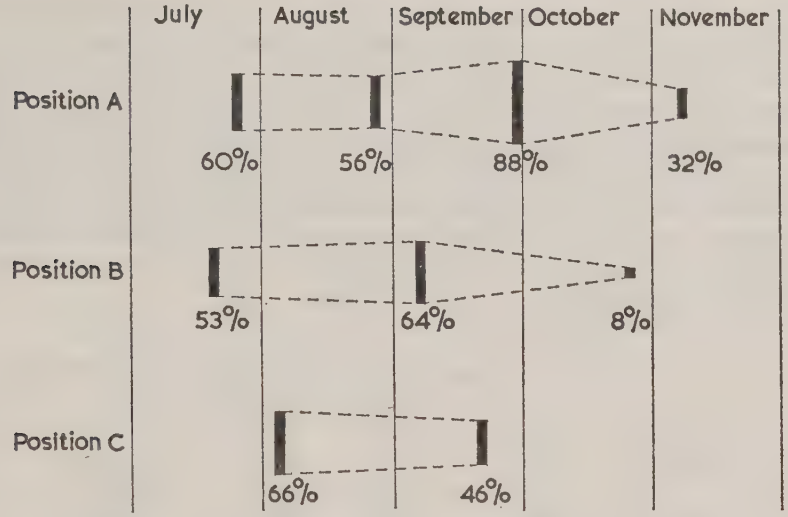

Figure 12. Incidence of *Trichodina* infestation in three environments during course of experiment.

Figure 12 shows the percentage incidence of *Trichodina* sp. at the three positions. From July to almost the end of September the infestations were all fairly similar, ranging from 46% to 64%, but the last two samples from the natural population at position A in November and the final sample from position B in October show a decrease in infestation.

Table XII shows the incidence of this species at different population densities. At both B and C the incidence was higher at the greater population density, as may be expected of a parasite with the mobility and the direct life cycle of *Trichodina*.

TABLE XII

INFESTATION WITH *Trichodina* sp. AT DIFFERENT POPULATION DENSITIES

Position	Date	Population density	Incidence		
			No. examined	No. infested	%
B	20/7/65	30	26	8	31
		100	25	19	76
C	4/8/65	30	15	8	53
		100	23	16	70

Tripathi (1948) showed that *T. branchicola* was very sensitive to changes in salinity and temperature, a feature it shares with other species of *Trichodina* for which the relevant data are available. This sensitivity might explain the observed decrease in the incidence of *Trichodina* sp. in O-group plaice at Loch Ewe in the autumn, when variations in temperature and rainfall are usually wider than in the summer.

Scyphidia sp.

No species of *Scyphidia* appears to have been recorded previously from any species of flatfish, but three have been recorded from other marine fish. These are: *Scyphidia scorpaenae* Fabre-Domergue, recorded from *Scorpaena* by Fabre-Domergue (1888), *S. gasterostei* Faure-Fremiet from *Gasterosteus aculeatus* by Precht (1935), and *S. acanthoclini* Laird from *Acanthoclinus quadridactylus* (Forster) by Laird (1953). *S. scorpaenae* and *S. gasterostei* were both recorded from European waters and *S. acanthoclini* from New Zealand waters.

Unlike *Trichodina*, *Scyphidia* is a sedentary species which attaches itself firmly to the gill filaments and feeds from the flow of water passing over the gills. Laird (1953) made an interesting comment on methods of examining gills for these ciliates: ". . . only those smears from crushed gills were positive for scyphidians. The reason for this is that the latter peritrichs are so firmly attached to the gill lamellae by means of the scopula, that superficial smears made in the normal manner only rarely result in their being dislodged. This fact indicates that the incidence of *Scyphidia* on *A. quadridactylus* is much higher than field results had suggested, and may perhaps help to account for the general paucity of records of members of this genus from marine fishes." The method of examination described for *Trichodina* was employed to estimate the numbers of *Scyphidia* on the gills of O-group plaice at Loch Ewe. The highest estimated infestation was 945, on the gills of a fish from the natural population on 10th November.

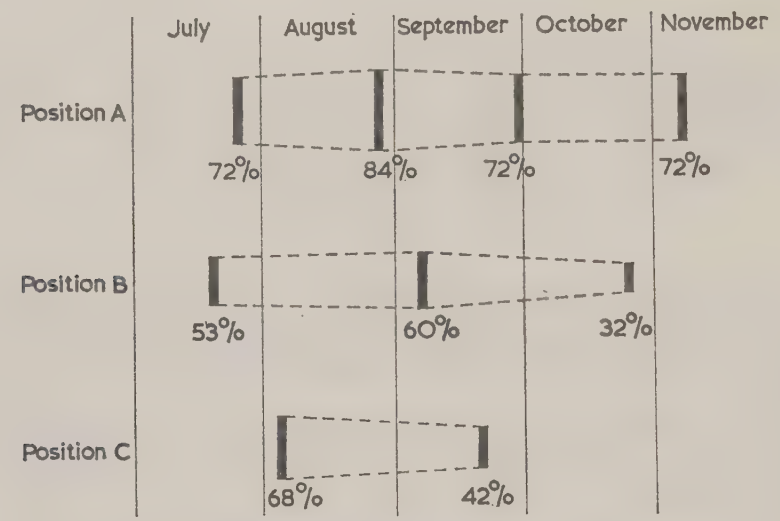

Figure 13. Incidence of *Scyphidia* infestation in three environments during course of experiment.

Figure 13 shows the percentage incidence of *Scyphidia* at the three positions. The heaviest infestations were all from the natural population. The pattern of infestation in the tank fish was similar to that for *Trichodina* except that the incidence of *Scyphidia* at position B on 25th October was considerably higher than the incidence of *Trichodina* in the same sample. The incidence figures for *Scyphidia* generally do not show such a large decrease in the autumn as for *Trichodina* which may indicate greater tolerance of variations in salinity and/or temperature.

Table XIII compares the incidence of *Scyphidia* at different population densities. The incidence of this species was greater at the lower level of population density. It is interesting to note that the incidence at the ower population densities approximated to that in the natural population at about the same time.

TABLE XIII

INFESTATION WITH *Scyphidia* sp. AT DIFFERENT POPULATION DENSITIES

Position	Date	Population density	Incidence		
			No. examined	No. infested	%
B	20/7/65	30	26	16	62
		100	25	11	44
C	4/8/65	30	15	12	80
		100	23	13	56

Sphaerospora irregularis Kabata, 1962

This myxosporidian was described by Kabata (1962) from the urinary bladder of the long rough dab [*Drepanopsetta* (*Hippoglossoides*) *platessoides* (Fabricius) Malmgren] in the northern North Sea.

Data on *S. irregularis* are available for only four samples of O-group plaice from Loch Ewe; the incidence of *S. irregularis* in these samples is shown in Table XIV. These limited data suggest that the incidence of infestation was greater at the higher population density. This is to be expected with parasites which have direct life cycles and are dispersed by releasing spores into the water.

TABLE XIV

INFESTATION WITH *Sphaerospora irregularis* IN O-GROUP PLAICE

Position	Date	Population density	Incidence		
			No. examined	No. infested	%
B	20/7/65	30	26	5	20
C	4/8/65	30	15	2	13
C	4/8/65	100	23	10	43
B	25/10/65	100	25	4	16

Unidentified Parasitic Dinoflagellate

One O-group plaice, from the tank with 30 plaice at position B on 20th July, carried a large number of the dinoflagellate shown in Plate III. These organisms, 238–250 μ long, were found attached to the gill filaments and free in the stomach. They resemble species of *Ellobiopsis*, which normally infest marine copepods.

COPEPODA

"Chalimus" Larvae

These are larval stages of parasitic copepods of the family Caligidae. Three specimens, 1·0, 2·2 and 3·2 mm long, were found in the natural population in July, August and September. They were attached to the fins by filaments in the usual manner, one on the right side of the tail fin and one each on the left side of the ventral fin and on the left side of the dorsal fin.

DISCUSSION

The comparisons of parasitic infestations in different environments presented in this paper serve to illustrate the very local character of marine parasitic infestations. The three positions in Loch Ewe used in this experiment are within five miles of one another and yet considerable differences are evident in the parasite faunas of O-group plaice at these positions.

The environment at position C differs in several respects from that at position A and B, the differences being reflected by corresponding differences in the parasite faunas of the O-group plaice. Position C does not support a natural population of young plaice, and the results presented in this paper suggest that infestations by at least two parasite species may be contributing factors to this situation. These are *Cryptocotyle* sp. and *Contracaecum aduncum*, each of which was present in plaice at position C in much higher concentration than at A or B.

The environment at position B is similar to that at A, and the two positions are separated by a distance of only $1\frac{1}{2}$ miles. From July to September the parasite faunas of O-group plaice were also similar, but the last sample from position B changed the picture completely. At this time three of the adult trematode species and the two species of ciliate Protozoa were shown to have followed completely different paths of infestation in the tank fish at position B and in the natural population at A. It is difficult to account for these differences, but they may have been due to local environmental changes at one or both of the positions.

Parasite species with direct life cycles which spread by contact, like *Trichodina* sp., or by releasing spores into the water, like *Sphaerospora irregularis*, will obviously be favoured by high population densities, but over the relatively short period of time of this experiment no significant differences between the incidences of digenetic trematodes at different population densities would be expected. Exceptions to these general rules are found in the figures relating to *Scyphidia* sp. and *Rhipidocotyle* sp., for which no satisfactory explanation can be given.

Several of the parasite genera discussed in this paper are known to be potentially harmful to the health of their fish hosts; it is possible that heavy infestations could even prove fatal. Digenetic trematodes generally prove more harmful to their intermediate hosts than to their final hosts. Parasites of the genera *Gyrodactylus* and *Trichodina* are well known as harmful parasites of young, fresh-water fish, and *Contracaecum aduncum* has been shown by Petrushevski and Kogteva (1954) to have a significant, depressing effect on the condition factor of the Baltic cod, *Gadus morhua callarias* L. Thus the parasites considered in this paper which are most likely to cause loss of condition or death in young plaice are the digenetic trematodes *Stephanostomum baccatum*, *Cryptocotyle* sp. and *Rhipidocotyle* sp., the monogenetic trematode *Gyrodactylus* sp., the nematode *Contracaecum aduncum* and the ciliate *Trichodina* sp.

When fish are reared intensively in ponds or fish farms, ideal conditions for the propagation of their parasites may be created incidentally. Before embarking on such a project it is desirable, therefore, to know as much as possible about the biology and life cycles of the relevant parasites so that adequate control measures may be taken. The first step in developing control measures for a helminth parasite is to determine its life cycle; thereafter the parasite can be attacked at its most vulnerable stage. At present the life cycles of most of the plaice helminth parasites considered in this paper are unknown. Further research will therefore be directed towards the determination of these life cycles, the main objective being the control of harmful parasites in fish farming projects.

The author wishes to thank Dr J. H. Steele of the Marine Laboratory, Aberdeen, who conducted the experiment on which the above work was based and provided facilities for the collection of samples. Thanks are also due to Dr Z. Kabata for translating references, Dr R. R. C. Edwards for collecting samples and providing data on plaice diets, Mr W. B. Hall for statistical analysis and Mr J. D. Milne for preparing illustrations.

SUMMARY

The parasites of O-group plaice living under artificial conditions in open-mesh submerged tanks in Loch Ewe, a sea loch on the west coast of Scotland, are compared with those of the natural population of O-group plaice in the same loch. Two positions, one providing a sandy substrate in an open situation and the other a muddy substrate in a sheltered situation, were chosen for the experimental tanks. The natural population was sampled from a third position in an open sandy bay.

From the 263 plaice examined in the course of this study 19 species of parasites were recorded, including representatives of Digenea, Monogenea, Nematoda, Cestoda, Acanthocephala, Protozoa and Copepoda. Data on the incidence and intensity of infestation of each parasite species are presented. Potentially harmful parasites of young plaice under intensive fish farming conditions are indicated and discussed.

The influence on each parasite species of two levels of plaice population density in the experimental tanks is considered. The higher level of population density is generally shown to favour the spread of parasites with direct life cycles, whereas those requiring intermediate hosts are largely unaffected by population density over the relatively short period of time (about one month) of this part of the experiment.

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